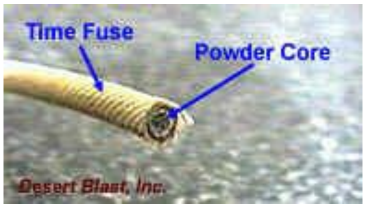
AERIAL SHELLS

The following is the procedure that has been used to assemble aerial shells for many years. Aerial shells are launched from a mortar (a specialized cardboard or HDPE plastic pipe), sending the shell high into the air with its time delay fuse lit. When the shell reaches its maximum altitude, it explodes, igniting the colored stars inside and throwing them a great distance.

Like all fireworks, these are by no means safe to manufacture and doing so is illegal in the United States unless you are licensed by the BATF. An assembled aerial shell "going off" on the ground in front of you (instead of hundreds of feet in the air) will most likely kill you or leave you disfigured for life. These directions will work for 4" through 8" shells, the sizes most commonly used by shell makers. We show the assembly of a 6" shell because it's a little easier to work with and photograph. Shells smaller than 4" generally can be assembled in a simpler fashion and shells larger then 8" (which we're not going to cover at all) get a lot more complicated.

To save time and trouble, most people pretty much stick with using plastic shell casings (as opposed to paper). Although these directions will apply to any size, the most common are 4", 6", and 8". One thing to do before assembling a plastic shell is to make sure the 2 halves fit together without effort. This may sound strange, but we've run into several bad casings that just don't fit together (and it can be quite aggravating to find this out after you've spent time loading your shell).

PART ONE: FUSING

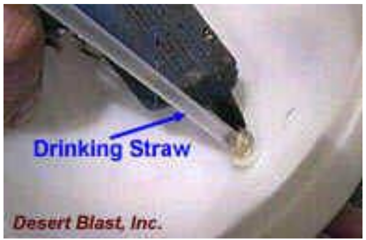


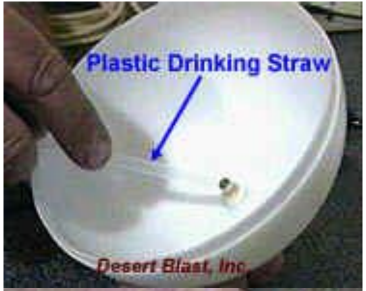
The time-delay fuse used in aerial shells is known as 1/4" Time Fuse or Oriental Time Fuse. It is available in coils of different lengths and has a nominal outer diameter of 1/4" (although occasionally you will see other diameters for sale; stick with the 1/4"). All 4", 6" & 8" shells use the same length of fuse: 1 1/4".

It is important that time fuse is cut with a blade (we recommend a Fuse Cutter) and not a scissor-type device. The powder core is somewhat fragile and if cut with a scissors or similar device the end is crushed (to varying degrees) and the powder loosened from its packed state, increasing its burn rate.

Insert a 1 1/4" long fuse into the bottom half of the shell, leaving about half the length sticking out of the bottom of the shell.

Using a Hot Glue Gun, lay an even bead of glue around the base of the fuse, sealing it to the casing. When cool, do the same on the inside of the shell. It is important that there be no gaps in the glue which could allow fire to enter the shell during launch.





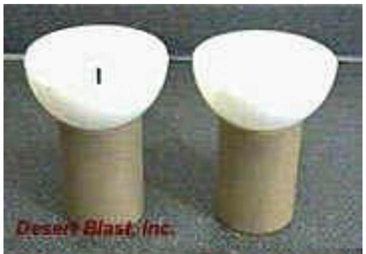
Slip a plastic drinking straw over the fuse end on the inside of the shell and glue into place. There are some straws that are either too small or too large to fit over time fuse; these are, unfortunately, usually the "free" ones you'll find at your favorite fast food restaurant. What will fit are the "Flexi-Straws" found in just about every supermarket. They come in boxes of 100 and are very inexpensive.

Cut the straw off so it's just under the rim of the shell.

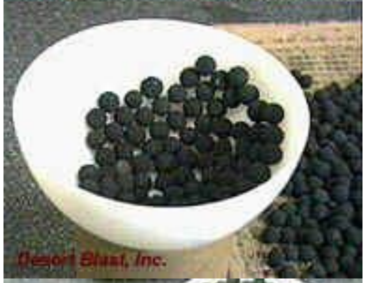
Fill the straw to within 1/4" of the top with granulated black powder. We use granulated homemade black powder. Its manufacture is described in the Black Powder Manufacture section. Commercial 3FG or similar may also be used.

Roll up a small ball of tissue and push it into the end of the straw with a nail or pencil. It shouldn't be too tight, just tight enough to hold the powder in and not fall out when the shell is turned over. Lay a ruler across the rim to make sure that the fuse tube does not protrude over the edge. If it does, just clip it shorter.

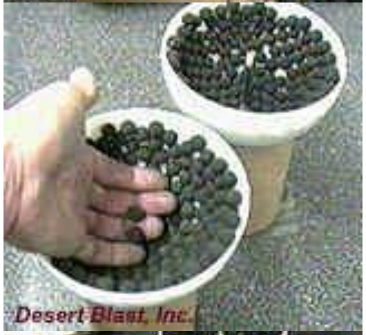
PART TWO: LOADING



Now that your shell is properly fused, it is ready to load with stars and a break charge. For ease of assembly (and to protect the fuse protruding from bottom half), set the two hemispheres on cardboard tubes or cups.



Starting with the top half (the one without the fuse), begin loading stars into the shell. Spread them one layer deep all around the inside of the hemisphere.

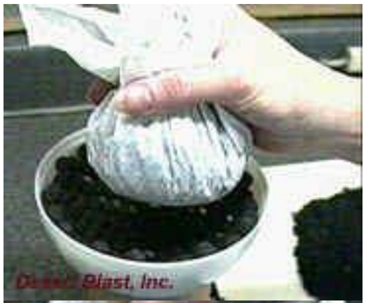


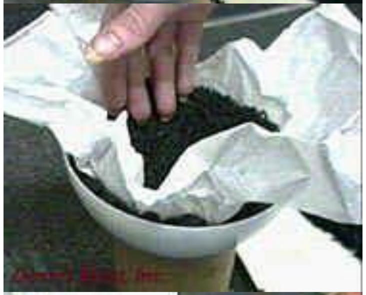
Continue loading until both halves of the shell have a layer of stars along the inside. Do not load the stars all the way up to the rim. There is a small lip on shell halves that must fit together, so leave a space of about 1/4" from the rim on both halves.

Next, you will need some tissue paper, the kind that you wrap fragile items in or pack Christmas presents with. You can certainly use other types of thin paper, even a 1-ply paper towel, but tissue paper is thin, strong, and easily obtainable.

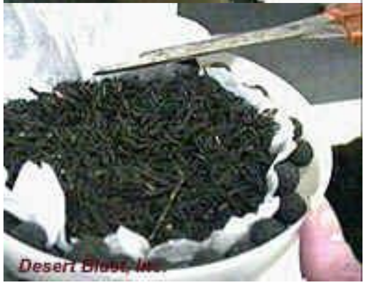
The next thing you'll need are some Meal Coated Rice Hulls (info on making them can be found in our BP Coated Corn Cob & Rice Hulls section).

Cut a piece of tissue paper about 12" square, form it into a little cup, and dump a heaping handful of coated rice hulls into it.

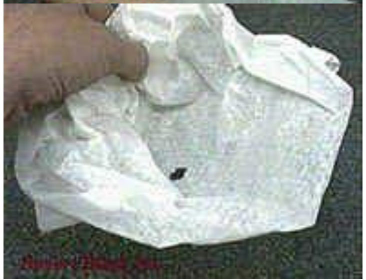




Hold the package of hulls by the top and drop it into the shell, quickly spreading the hulls up against the wall of stars. The rice hulls pressing on the stars will prevent them from falling in. The tissue paper merely prevents the stars from migrating into the center of the shell during transport or launch.

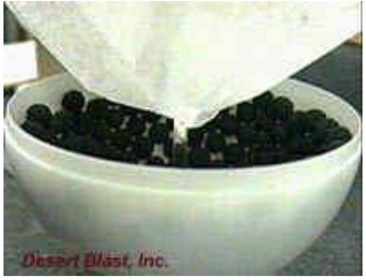


Trim the tissue paper so that it's under the lip of the shell casing. Add or remove some rice hulls until the shell is full to about 1/8" from the top. Check with a straight edge and be careful not to overfill, as this will make it difficult to assemble the shell. Set this half of the shell aside when complete.



Loading the fused side of the shell with hulls is a tad more difficult...

Cut another 12" square of tissue paper and tear a small 1/2" diameter hole in the center. Form it into a little cup with the hole at the bottom.



Now gently slide the paper cup over the straw and let it rest in the shell. If you bump the shell, your stars will go tumbling to the bottom, so be careful.

Get a cupful of coated rice hulls and all at once, dump the entire cupful into the shell. Do not do this slowly; the stars will fall in. If you just dump it in all at once, the hulls will hold the stars in place before they've got a chance to fall. Spread the hulls around evenly.

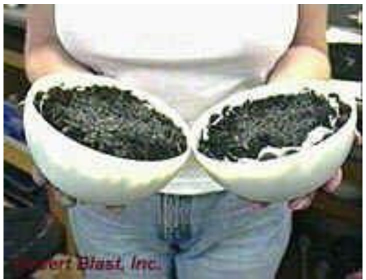
Trim the tissue paper all around the shell and make sure that it doesn't extend above the rim.

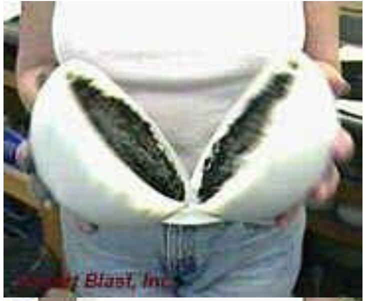
Do the same as you did on the other shell half, adding or removing hulls until the shell is full to just about an 1/8" under the rim.

PART THREE: FINISHING & CLOSING

Dump half a tablespoon of Whistle Mix in each shell hemisphere. The formula for whistle mix and can be found in the **Making Fireworks & Chemical Experiments** section. Some pros like to use flash powder (as shown in the images), but stick with whistle mix. Flash powder frequently breaks the shell too hard, smashing the stars into dust, or shoots them out so fast that they blow out. You'll find that whistle mix works perfectly almost all the time.

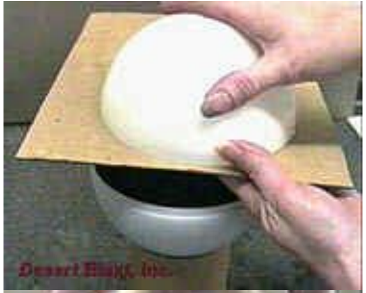
The shell is now ready to be closed. There are two ways to do this. You can simply snap the two halves together (as we do) or you can hold a piece of thin cardboard over one half. We'll show you both ways:



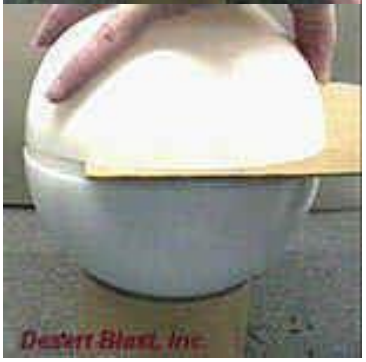


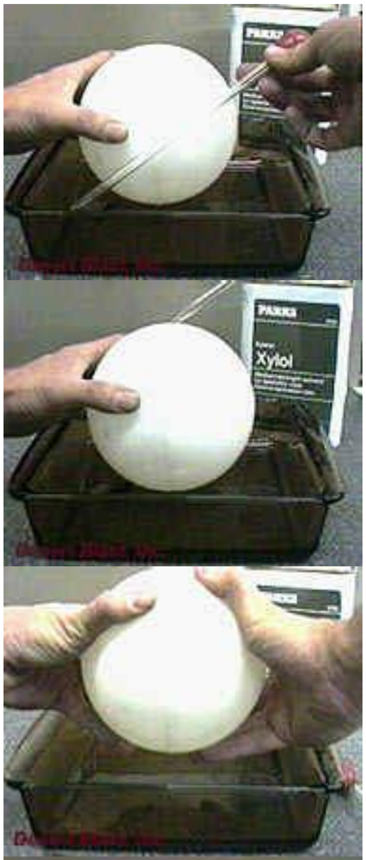
The quick way is to line up the two shell halves. One has a lip that fits inside the other. Rest the opposing shell on the lip and tilt them a little toward each other.

With one fast move, snap the shell together. I know, it looks like everything will go flying, but every person who we've taught to do it, does it with ease. If you feel you lack the coordination to accomplish this daring maneuver, try the alternate method:



Place a thin piece of cardboard (like the kind you find on the back of note pads) on one half of the shell. Holding it in place, flip the shell over and lay it on the bottom half. Align the two halves, and slowly pull out the cardboard, snapping the two hemispheres together.

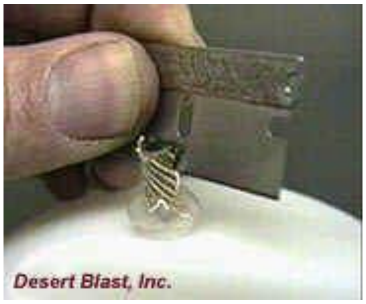




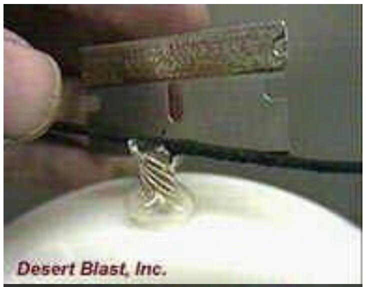
The shell is now ready to be sealed (you'll need a glass or metal container to catch the excess solvent that will drip off). Pull the shell just a hair apart (not too much, just a hair) and using either Xylol or Methylene Chloride in an eye dropper (squirt bottle, or similar), run the solvent around the seam of the shell. Rotate the shell so there are no dry gaps. Capillary attraction will draw the solvent into the seam and melt the plastic shell lips together. Before the solvent dries, push the shell halves firmly together, making sure that the shell is perfectly sealed.

Support the shell and orient it so the time fuse is pointing up. The next steps will be the final fusing of the shell and attachment of the lift charge.

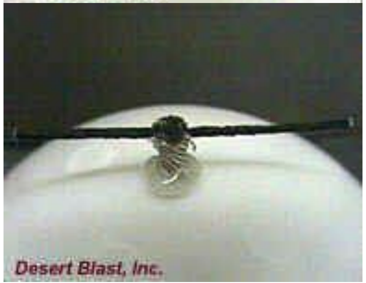
PART FOUR: FINAL FUSING & LIFT CHARGE



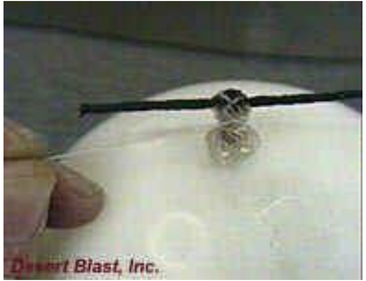
Using a razor blade, slice the time fuse in half to a depth of about 1/4"



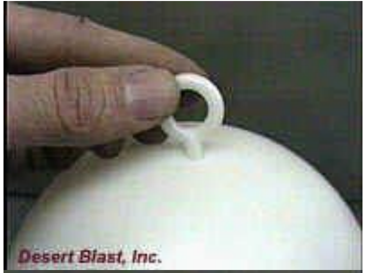
You'll need some Black Match, also known as "Crossmatch" (black powder coated cotton string) for the next step. You can see how that is made in our **Blackmatch and Quickmatch** section.



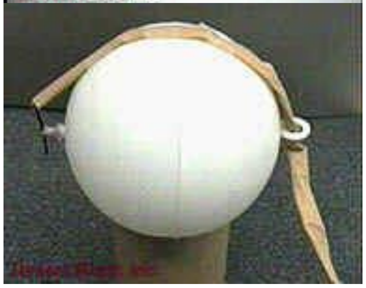
Rock the blade back and forth to open up the time fuse and insert a 3" long piece of crossmatch. Push the crossmatch in so it's level with the top of the time fuse.



Using some good quality thread (or better yet, dental floss), wrap a few turns around the time fuse and the crossmatch, securing them together. Tape the loose ends of the thread to the shell casing.



Flip the shell over, dip the fuse ring (that came with your shell casing) in some solvent and insert it in the top hole. The fuse ring will support the shell as it is loaded into the mortar.



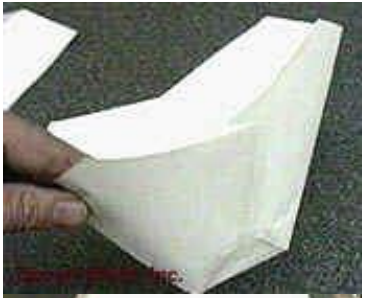
Lay the shell on its side and run a 4 foot length (approximately) of quickmatch through the fuse ring and around the shell, ending at the time fuse. The quickmatch doesn't have to actually touch the crossmatched time fuse. They will both be inside a pouch of lift powder (granulated black powder) and will ignite simultaneously. Tape the quickmatch to the shell casing every few inches so it is secure. The quickmatch needs to be about 18" longer than the mortar you will be using to fire your shells.

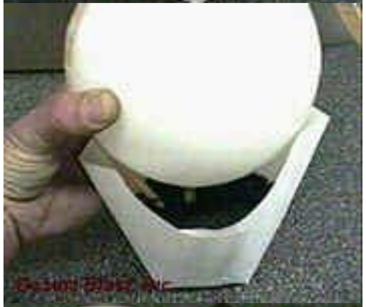
The final step is to add a pouch filled with lift powder (coarse granulated black powder). We use homemade lift powder, although commercial FFG or FFFG Black Powder can be used. If commercial black powder is used, the amount of lift charge is cut just about in half due to its faster burning speed. Directions for making Lift Powder can be found **here**. Lift charges are as follows:

	4" Shell	**6" Shell**	**8" Shell**
Homemade lift powder	60 grams	100 grams	200 grams
Commercial black powder	35 grams	60 grams	100 grams

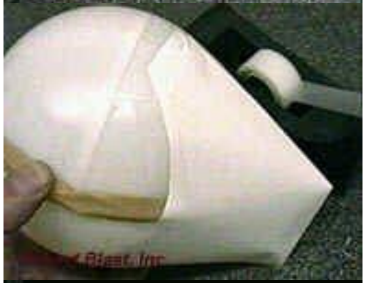
These lift charge amounts should only be taken as "ballpark" figures. There are many factors which come into play when determining the amount of lift charge to use; relative "strength" of the black powder, particle size, etc. One additional parameter is the length of the mortars. Just as a point of reference, our 4" mortars are 24" long and our 6" mortars are 36" long.

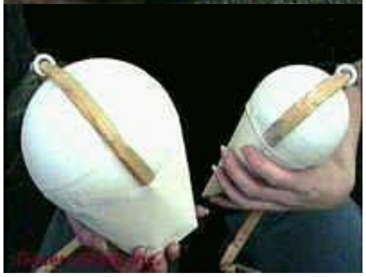
A small pouch must be attached to the bottom of the shell to hold the lift charge. For the smaller 4" shells, "Solo" cone-shaped paper cups can be used. They're cheap and easily obtainable. Regular "Dixie" paper cups cannot be used because they're coated with wax, making it difficult to attach them to the shell.
Or check out our **Lift Cups**!





Larger shells require that you fashion a pouch out of paper. A single sheet triangularly folded with the ends trimmed and taped makes an excellent pouch. Of course, any design can be used just as long as it can be attached to the shell and it doesn't leak out the lift powder inside. The pouch is filled with the appropriate amount of lift powder and then securely taped to the bottom of the shell.





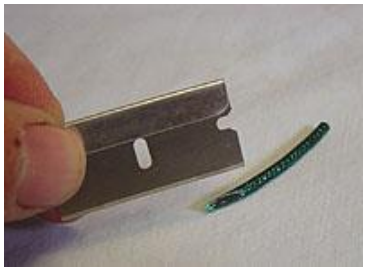
Completed aerial shells (6" shell and 4" shell).

Always remember to tear off 12 to 18 inches of paper off the end of the quickmatch fuse for delay before launching. As stated before, aerial shells are complex and dangerous fireworks. Although this description of the assembly procedure is complete, many of the potential problems and warnings have not been addressed. Never attempt the construction of these devices unless you are licensed and have been properly trained to do so.

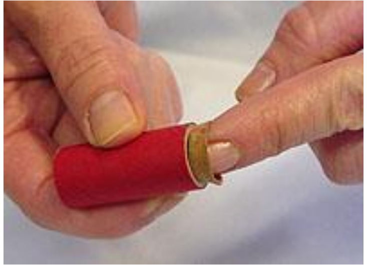
AERIAL MORTARS

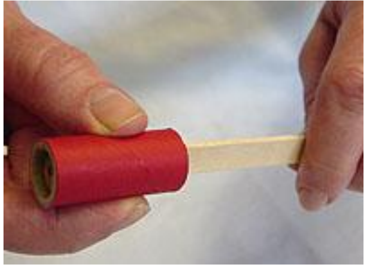
An Aerial Mortar is basically a tiny tube that shoots a small tube projectile, called a "shell," high into the sky. The shell can contain a whistle, star, smoke bomb, or other firework effect. The shell is timed to ignite when it reaches its highest point (known as the "apogee") in the sky. The aerial mortar is composed of two main parts; the mortar (launch tube), and the projectile (shell).

THE SHELL PROJECTILE

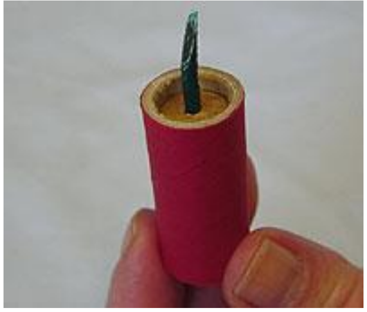


Take a 1-1/2" piece of **Visco Fuse**, and using a razor blade or **Fuse Cutters**, cut one end in a sharp diagonal. This is done in order to expose a larger amount of the black powder core inside the fuse and ensure that it will ignite during launch. Do not cut the fuse with scissors or similar tool. Not only are scissors an ignition hazard, but they also do not make a clean cut; they can actually simultaneously crush the powder core and close the fuse end, making ignition much less reliable. There is no need to cut a diagonal on the other end of the fuse.





This end plug is going to be the bottom of the shell (projectile), and to make it strong enough to withstand the blast of launching it out of the mortar, we're going to use it backwards in the tube and reinforce it. Be sure to punch a hole in it for the fuse. Press the end plug in one end of the tube, and using a small stick or pencil, push the plug all the way to the other end, leaving a full 1/2" of space above it. This space is important; it will serve as the time delay.



Insert the 1-1/2" piece of fuse (with the diagonal end sticking out) so about 1/2" is outside the shell.

Stand the tube up, and fill the empty space with Elmer's White Glue. This will have to dry for several hours if not overnight before you can continue. It is possible to use hot glue in place of Elmer's at this point if you're impatient; you need only to wait until the glue cools, which should be in about 15 minutes. It should be noted, however, that we have had a few misfires using hot glue, and Elmer's is really the better choice. It's possible that under the right conditions the molten glue surrounding the fuse effects the powder core in some way. In any case, if you're just too impatient to use Elmer's, and do use hot glue, be sure to use a low-temperature gun and low-temperature glue sticks. This 1/2" thick gap that you filled with glue will serve as the time delay for the shell. Safety Fuse burns at about 3 seconds per inch, so it takes the fuse about 1.5 seconds to burn through the 1/2" thick glue plug you just made. This gives the shell time to reach its maximum altitude before the fuse burns all the way through into the powder. You can adjust this delay by making the glue-filled gap thicker or thinner. If the projectile ignites before reaching its maximum height, make the plug thicker. If it ignites after it reaches its maximum height and is on the way back down, make the plug a bit thinner.

Fill with your favorite pyrotechnic composition

Smear some Elmer's glue around the lip of the tube and press in the other end plug. Push the plug into the tube so there's about a 1/16" gap between the tube end and the plug edge. This is just so we've got another anchor point for more glue between the tube and plug. Smear a good quantity of glue around the rim so the end plug will be locked into place. This end of the tube MUST be glued with Elmer's, not with hot glue. Since the glue layer is not very thick, it will not take that long to dry.

Set the completed shell aside to dry.

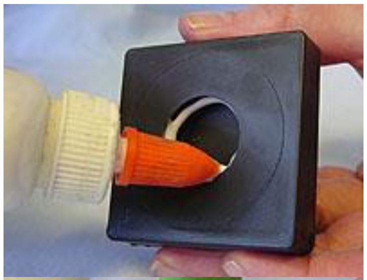
THE MORTAR

The mortars for the aerial mortar come in 2 pieces; a small plastic base, and a heavy-wall launch tube. We offer 3 sizes:

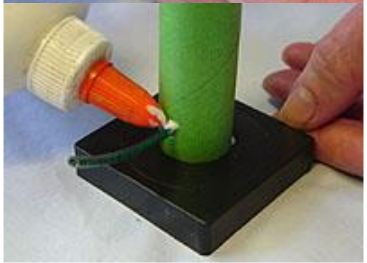
3/4"   1"   1 1/4"

Test fit the two pieces and see if they fit together. If they don't, use a file and just file a bit off the edge all the way around the tube so it's possible to press it into the base.

Using an 1/8" drill, make a hole 3/4" from the bottom of the tube. This will be the fuse hole.

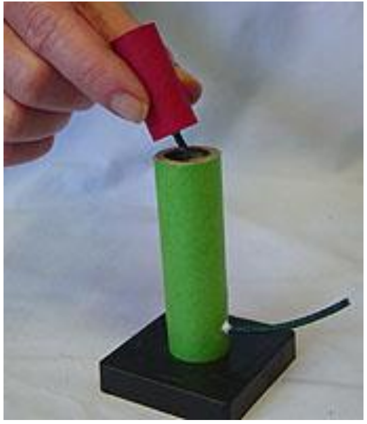


Spread some Elmer's or hot glue around the indent in the base and firmly press the tube into the base. Make sure that the tube is pointing up straight from the base.



Cut a 3" piece of Visco Fuse and insert it all the way into the hole. Spread a little Elmer's around the hole to hold the fuse in place if it is loose.

Pour in a 1/8 TEASPOON of granulated black powder into the mortar.
Instructions on making black powder, as well as converting it into granulated black powder (lift powder) can be found **here**.
You can also use commercial 2FG or 3FG Black Powder if you don't want to make your own. You CAN NOT substitute flash powder for the granulated black powder. Black powder burns slow, and even slower when it is granulated. We want to gently (but quickly) launch the projectile out of the tube and ignite the delay fuse.
If you were to use flash powder (in any amount) in the launch tube, it would detonate and destroy the mortar, and also destroy your projectile.



Push your shell (fuse first) all the way down into the mortar. The shell should slide easily down into the tube; you should not have to force it. When completely dry, the completed aerial mortar will be ready for use.

OPERATION

When the fuse is lit, the granulated black powder ignites, shooting the shell up into the air. At the same time, the flame from the lift charge ignites the delay fuse on the shell. When the fuse burns out, the shell ignites in the air. Remember that for every action, there is an equal and opposite reaction. This means that the same amount of force that is shooting the projectile up in the air is pushing back down on the mortar tube. Thus, you should make sure the device is on solid, flat ground. Like everything, the aerial mortar may require some fine tuning. You might have to adjust the amount of black powder (lift powder) or the time-delay plug thickness to get the shell to ignite at the proper time. Don't even think about holding this in your hand and lighting it. It is always possible for the firework to malfunction and explode or flare up.
BE CAREFUL! Under the proper conditions, even fairly "safe" firework compositions can explode violently and cause great injury.

BLACK MATCH

"Black Match" is simply a cotton string covered with black powder. When a small piece of black match is inserted in a length of Japanese Time Fuse, it's then called "Crossmatch." If black match is covered in a thin paper tube, it burns hundreds of times faster than normal and is called "quickmatch." All in all, crossmatch, black match, and quickmatch are all essentially the same, and are made from lengths of cotton string covered with black powder.

MANUFACTURE

To make black match, you're going to need 4 things: a plastic container with a snap-on lid, a 1/8" drill bit, some meal powder (which is just very finely powdered black powder), Cotton string, and a little dextrin. Make sure you get Cotton string, not nylon or any other synthetic material. The string must be Cotton and must be able to absorb water quickly. The best you can get will be from a fabric store. They usually sell unbleached Cotton string, which is by far the best thing to use, although ordinary white Cotton string will work fine. Make sure the string is less than 1/8" diameter. The ideal string is about 1/16" Cotton string, although any size under 1/8" can be used.

The first thing to do is to drill a 1/8" hole in the lid to your plastic container. Don't just poke a hole through the lid, the hole must be a clean, smooth 1/8" hole free of burrs.

Pour 50 grams of meal powder and **2.5 grams of dextrin** into your plastic container.

While stirring, add a little water at a time until the mixture forms a runny paste (about the consistency of ordinary Ketchup).

Cut a 3 foot length of Cotton string and carefully coil it into the meal powder paste, pushing it down into the mixture until it is completely covered.

Thread the other end of the string through the 1/8" hole in the plastic lid. Leave about 2" sticking out of the hole.

Snap the lid on the container, and set the whole thing on the ground.

Slowly, pull the string through the hole, and it will emerge perfectly coated.

Using some tape, or better yet a thumb tack, attach the coated string to an overhang to dry. It's very sticky and messy while wet, so be careful not to let it touch anything until it's dry.

After a couple of days, your black match will be dry and quite stiff. Cut off a small length and test it outside. It will catch fire easily when lit, and burn just like a fuse. If you take a longer length of black match and cover it in a thin, tight paper tube, you'll find that it burns much faster. This is known as quickmatch. The faster burning is due to the pressure increase inside the tube. As the black match burns, hot gasses and flame build up in the tube and is forced down the length of the thin paper tube at high speed. Some commercial quickmatch can burn at almost 500 feet per second.

BLACK POWDER

Black Powder is the backbone of pyrotechnics. After all, it's black powder that gives fireworks the smell we all love so much. Black powder is the main ingredient in a variety of firework and rocket formulas. You can easily make your own high quality black powder with just a few chemicals and a ball mill.

BASICS

Black powder is also known by a couple of other names. The most common is Gun Powder. Black powder is produced in large quantities commercially, and sold in small 1 pound containers, mainly for use in antique black powder guns. It is also normally sold in different granulations, and they indicate how fine the black powder is granulated by how many "F's" they put on the container. Coarse granulations are called "FG or FFG" (aka "1Fg" and "2Fg"). Finer granulations are "FFFg and "FFFFg" (aka 3Fg and 4Fg). The more "F's", the finer the black powder...and the finer the black powder is, the faster it burns. Small (fine) granulations burn faster and are used in small bore guns, where larger (coarser) granulations are used for larger bore guns and cannons, and for launching aerial shells out of mortars. Using a finer granulation for these jobs puts too much strain on the gun (or shell or mortar) because the powder burns much faster and creates a fast pressure increase that could damage whatever you're trying to launch, or the gun/mortar itself. Coarser, granulated black powder that is used in mortars to launch shells, or in Roman Candles to shoot out stars, is sometimes called "lift powder." When black powder isn't granulated, and is in a super fine powder state (similar to that of Talcum powder) it is called "meal powder." Just to confuse things even more, any granulated black powder is also sometimes called "grain powder."

Smokeless Powder (Pyrodex, etc.) is not to be confused with black powder. It is actually nitrocellulose, and cannot be used in place of black powder. Now, why they needed 5 names to describe one substance is beyond us, but just keep in mind that black powder, gun powder, lift powder, grain powder, and meal powder are really all the same material. 30 years ago (when I was 13), I sat picking the raisins out of Oatmeal because I thought meal powder was just finely powdered Oatmeal. Needless to say, the rocket engine I was building didn't work, as Oatmeal doesn't have quite the kick that black powder does. On the other hand, black powder makes a terrible breakfast.

Anyway, as far as fireworks are concerned, black powder is used both in its finely powdered form (meal powder) for coating stars and for mixing in other pyrotechnic formulas, and in its granulated form (lift powder) for launching shells out of a mortar, or stars out of a Roman Candle.

The formula for black powder is 75% potassium nitrate, 15% charcoal, and 10% sulfur, and like all formulas, it is measured by weight only. However, unlike many pyrotechnic formulas, you just can't mix these chemicals together and expect to have black powder. The mixing process for black powder is just as important as the formula. Black powder **MUST** be made in a ball mill to work properly. A ball mill is a rotating drum with dozens of lead balls inside. The 3 chemicals are loaded into the ball mill, along with the lead balls, sealed shut and allowed to rotate for anywhere between 1 and 24 hours. As the ball mill rotates, the lead balls will crush the chemicals together, forcing some of the potassium nitrate into the pores of the charcoal and sulfur. At the same time, the entire mass will be reduced to a super fine powder. The longer the ball mill runs, the stronger the black powder will be. A general rule of thumb for all pyrotechnic mixtures is "the finer the powder is, the faster it will burn." **ONLY** lead balls can be used in a ball mill as they are completely non-sparking. **ONLY** black powder can be mixed in a ball mill. Other pyrotechnic mixtures such as flash powder **CAN NOT**, as they are too sensitive and will explode. Individual chemicals, however, can also be ball-milled into a fine powder, but the mill must be cleaned before this is done.

Once the mill has run for a while, it can be opened and the lead balls separated from the fine meal powder. As we'll show you below, this meal powder can now be used to make all the other forms of black powder for use in fireworks.

BLACK POWDER vs. FLASH POWDER

A lot of people ask which is stronger, black powder or flash powder, or if black powder can be used in Salutes (exploding fireworks). In short, there is no comparison. Flash powder is a high explosive; a shattering explosive. It converts to a gas so quickly that objects near it, and containers that hold it cannot move out of the way (or vent) fast enough to release this gas, so they are destroyed into fragments. Black powder is a low explosive; a heaving explosive. It converts to gas much more slowly than flash powder, and generally pushes things as opposed to fragmenting them. If black powder is used in a small Salute like an M-80, it will just make a loud "pop" and push out the end plugs. Flash powder in an M-80 will make a loud explosion and fragment the tube into small pieces. Flash powder burns so much faster than black powder that in larger Salutes, it doesn't even matter if you've got end plugs on the tube at all, it will still detonate and fragment the Salute, even with 2 open ends. You can **NEVER** substitute flash powder for black powder, or vice-versa. If you were to use flash powder to launch a shell out of a tube, or a bullet out of a gun, it would barely move the shell or bullet, and completely destroy the mortar or gun, probably injuring the operator.

MANUFACTURE

You will need 3 chemicals to make black powder: potassium nitrate, sulfur, and charcoal. Stay away from very low grade materials like "Dusting Sulfur" and Bar-B-Que Charcoal Briquettes. The charcoal you use in a BBQ is not pure charcoal. It contains other materials and chemicals that are designed to keep the material burning evenly and for a long time, but it will make lousy black powder. If you use low quality chemicals, you will undoubtedly get low quality black powder.

The following is the standard formula for black powder:

CHEMICAL	PERCENT/PARTS
Potassium nitrate	75
Charcoal	15
Sulfur	10

PROCEDURE

Open the lid to your **Ball Mill** and add the following:
150 grams of potassium nitrate
30 grams of charcoal powder
20 grams of sulfur
If your **Lead Balls** are not already in the tumbling barrel, go ahead and put them in now. Remember that ONLY lead balls can be used because they are completely non-sparking. When complete, this will make 200 grams of black powder (a little under 1/2 pound). You can make larger or smaller batches, just keep the percentages of all the chemicals the same. You MUST use an accurate scale to weigh your chemicals, preferably one that is accurate to 1/10th of a gram.

With all 3 chemicals and the lead balls inside, put the lid on the tumbling barrel and seal it, then set it in the mill. Turn on your ball mill and let it rotate for 2 to 4 hours. As the mill rotates, the lead balls will crush the chemicals together and reduce them into a super fine powder. The longer you let it grind, the stronger your black powder will be. Let the ball mill do its grinding in an uninhabited area, not in a place like your bedroom. Although the chance of accidental ignition is very remote, it is wise to put your mill in the garage, or better yet, outside, to do its work.

At the end of a couple of hours stop the mill. Lay out a sheet of paper (newspaper will work fine). Open the lid to the barrel, and dump the entire contents (lead balls and all) into a spaghetti strainer over your sheet of paper. The strainer will catch the lead balls and with a little shaking, all the black powder will filter through onto your paper sheet. When black powder is in a fine "dust-like" state like this, it is called "meal powder." The meal powder you've just made can now be used as-is in a variety of formulas and projects. By adding a little water and dextrin to it, you can easily make black match fuse or quickmatch. See our section on making **Black Match Fuse & Quickmatch**.

LIFT POWDER

There are some applications where very fine black powder (meal powder) will not work well. If you're going to use your black powder to launch shells out of a mortar, or for small cannons, it will have to be granulated first. Black powder that is granulated and used for launching shells and salutes is called "lift powder." The procedure for making lift powder is easy, but it sometimes takes a few tries to get it perfect. Basically all we're going to do is to add a little of a water soluble glue (dextrin) to the meal powder, mix it well, get it a little damp, and push it through the spaghetti strainer again. This will produce small granules of black powder perfect for launching shells or anything else. The whole trick to this is not to get the mixture too wet, or it will become gooey and just turn into a big mess.

To convert your meal powder into lift powder, take 100 grams of meal powder and mix in 10 grams of dextrin. A good way to mix them is to put the mixture in a plastic container with a snap-on lid and shake well. Pour the powder through the spaghetti strainer again; this will break up any lumps in the dextrin. Now place the meal powder/dextrin mix back in your plastic container and add just a little water. This is where experience really pays off. The idea here it to get the mixture damp and not wet. What can be deceiving is that you're adding water to a very fine powder, so it's going to take several minutes of mixing just to get the powder to begin to absorb any water at all. Add just a little water at a time, mixing thoroughly. As the powder begins to take in water, it will turn a bit darker in color. You want the mixture to be damp enough to where if you take a handful of it and squeeze it tightly, it will just begin stick together. You do not want to get it too wet. If you do, it will not go through the spaghetti strainer and will just clump up on the bottom, or not go through the holes at all. If disaster strikes and you have added too much water, you can always just add some plain meal powder to the mix to dry it out.

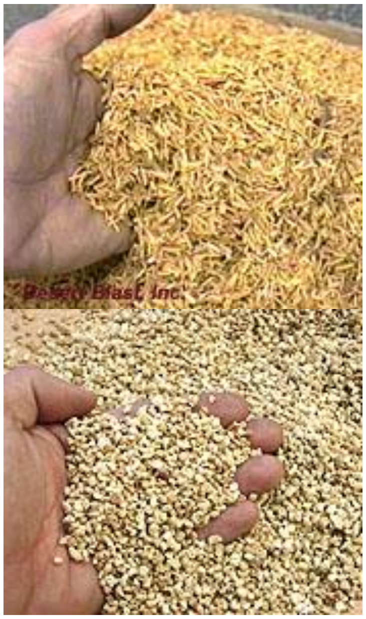
FYI: adding the water also increases the strength of the black powder by allowing some of the potassium nitrate to dissolve and be absorbed into the pores of the charcoal particles.

Once the mixture is damp, lay out another sheet of newspaper and dump the mixture into the spaghetti strainer. Using a wooden or plastic spoon (or your hands if you don't mind getting messy), rub the mixture through the screen, allowing the granules to fall onto the newspaper below. The lift powder you're making will have to dry for a few days before it can be used, so make sure to spread it around on the newspaper so it will dry more quickly.

If your mixture isn't all going through the screen, or is sticking on the bottom, chances are it's too wet. Take the mixture out of the strainer and mix in some plain dry meal powder and try again. If the mixture is going through easily, but isn't really making granules, it might be a bit too dry. Take the mixture out of the strainer and add a small amount of water, mix well and try again.

BP COATED CORN COB & RICE HULLS

Meal Coated Corn Cob (or Rice Hulls) is the explosive that is used to break open aerial shells and simultaneously ignite the stars inside without shattering them into dust. "meal powder" is nothing more than very finely powdered black powder (gun powder). Rice hulls are simply the shells of ordinary white rice. They look very much like grass seed, and if you really wanted to, you could use grass seed in place of rice hulls, but it's a very expensive alternative and there are much better (and less expensive) substitutes. There is nothing special about rice hulls, and in fact, you can use several other materials that are less expensive and work better, such as corn cob. The idea here is to have an explosive that is easily ignited, strong enough to break the shell and throw the stars a great distance, but not be so powerful that the explosion shatters the stars and renders them useless. If a small granular type material is coated with black powder, it burns much faster than just the black powder would alone. Coating the corn cob (or whatever you're going to use) not only increases the burning speed of the black powder, but the mixture is also far more bulky than black powder is alone. Because it takes up more space, it fills the empty gaps in the shell and holds the stars against the wall of the shell. Rice hulls have historically been chosen because they are considered to be a waste material and are essentially free. We're told that in some states, the local authorities pour rice hulls on the road for added traction in the winter. Although they may be very easy to get in some places, they are nearly impossible to get a hold of in others. A nice substitute that we've found works even better is corn cob. Corn cob is just what the name implies. It is dried and granulated corn cobs. In short, whichever material you choose, the procedure outlined below will work well for either.



Note the difference in appearance between Rice Hulls (top) and Corn Cob (bottom). Either one can be used in this process, although corn cob does work a bit better in aerial shells.

STEP ONE: MAKING THE DRYING BAG

The first thing you'll need to make is a drying bag, which is just a large "pocket" with a fold-over flap. We make one out of some old window screen, fold the edges over and staple with an ordinary staple gun. Make sure it is large enough to hold about a cup full of corn cob or rice hulls. Set this aside for now; we'll be using it later.

STEP TWO: PREPARING THE BP MIX

Weigh out 375 grams of black powder and place it in a large container. Make sure that this container has a lid that snaps on and will not leak.

Weigh out 75 grams of dextrin and place it on a piece of paper.

Take the dextrin that you've just weighed and run it through a strainer into the measured amount of black powder. This breaks up any clumps of dextrin so that it will evenly mix with the black powder when you shake it.

Snap on the lid to the container and shake the dextrin and black powder mixture until it's evenly mixed. Set this mixture aside.

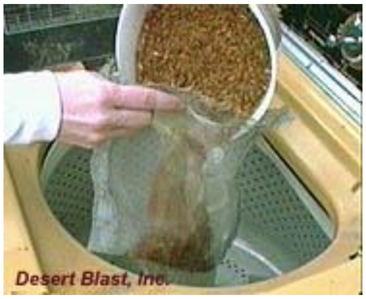
STEP THREE: WETTING

Measure out about a full cup of corn cob (or rice hulls), place them in a large plastic container, and add about 2 cups of warm water.

Tamp down the corn cob (or rice hulls) with your hands until they are all under water and wet.

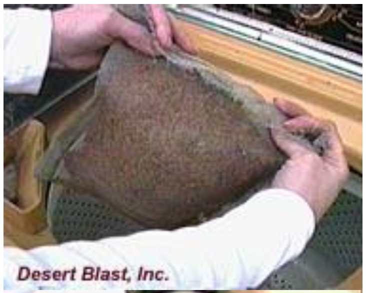
Let the corn cob or rice hulls soak for 20 minutes, occasionally stirring them and tamping down any that may become dry on top.

STEP FOUR: DRYING



What we're going to do now may seem a bit strange, but it works great. The hulls need to be just damp at this point; not wet and not too dry. You can either spread them out and allow them to dry to dampness (which takes several hours), or do it in 20 seconds flat using your washing machine. We use the washing machine as a large centrifuge by utilizing the "spin" cycle. Beware that your wife may kill you if she sees you doing this, so choose an appropriate time to dry your material.

After they have soaked for 20 minutes, open your drying bag over the washing machine, and pour in the soaking wet cob/hulls and water. The water will pour right through the screen bag and drain into the washer.



Fold over the top of the drying bag as shown to prevent any of the material from escaping during the spin.

Washers have a safety mechanism that disables the unit if the lid is opened. Although you don't need to bypass this feature, you can if you want to watch what's going on. To do this, look for the small tab or slot that the lid pushes in to tell the washer that it's closed. Generally, all you have to do is to stick a screwdriver in the slot and the washer will operate as if the lid was closed. This really doesn't need to be done, but we've done it to show the washer operating.

Before you actually spin the cob/hulls, make sure that you can select a "spin only" position on the washer control. You might have to play with the control a bit to find the exact place that will make the unit spin, but not to spray in water and rinse. Once you are confident that you can make it spin without spraying water, go ahead and set the wet bag of cob/hulls in there and turn on the spin cycle. **Allow the bag to spin for only 20 seconds**. Any longer will make the material too dry to use.

Remove the bag and have a look inside. They should be dark and damp, but not wet. Pour the damp cob/hulls into a large plastic container that you've got a lid for. Make sure that the lid fits well and doesn't leak. The container should be large enough to hold both the cob/hulls and the black powder with plenty of room to spare.

STEP FIVE: COATING

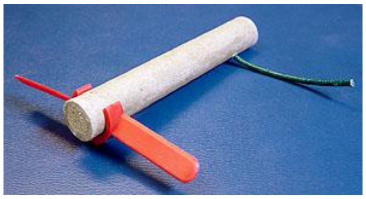
Combine the black powder/dextrin mixture that you made earlier with the damp cob/hulls. Snap on the lid, and shake well.

Lay out several sheets of newspaper (2 layers thick) and empty the coated material onto them. Break up any lumps that may have formed and spread the coated chunks out as thinly as possible. The coated material will become dry to the touch when left overnight, but will not be completely dry for a couple of days.

Be warned that you now have an explosive spread out on the floor. It is very flammable and it is vital that there are no sources of ignition anywhere in the area while the cob/hulls are drying. Do not attempt to speed the drying up by heating the cob/hulls in any way.

When dry, you can test the material by igniting a small pile of it (obviously far, far away from your large quantity of coated drying material). You'll notice that they burn very, very fast. Much faster than black powder does alone. This is because the fire can propagate faster around the outside of the cob/hulls and flash through the airspaces in between each piece. The coated Corn Cob (or Rice Hulls) can be stored until you're ready to use them in an aerial shell.

BUZZ BOMBS/HELICOPTERS



A very popular flying firework is the Buzz Bomb or Helicopter. Both are basically the same device, but the buzz bomb explodes with a loud report at the apex of its flight. There are a large number of variations to this particular firework, and we cover several in the procedures outlined below.

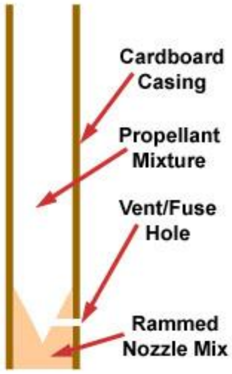
GETTING STARTED

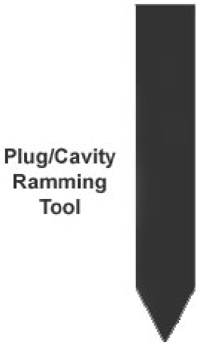
The helicopter is made from a [4 ounce rocket tube (1/2" ID x 5" long)](). Like all rocket-type devices, the tubes used must be parallel-wound to prevent bursting due to the high internal pressures generated. Parallel-wound tubes do not have the spiral seam that goes down the length of the tube (like the tube from a roll of paper towels or toilet paper).

Once you've got the proper tube, the first thing you'll need to do is make (or [purchase]()) some tooling. The reason for the tooling is to be able to form a hard plug and cavity at the end of the tube.

When lit, hot gasses, sparks and flame shoot out the small 1/8" vent hole at the bottom of the helicopter, making it spin and lift off the ground. If you were to make an exhaust hole in the cardboard casing alone, the intense heat and flame would widen the hole in a fraction of a second, reducing the thrust and making the helicopter just flop around on the ground.

What the tooling does is form a cavity of heat-resistant Rocket Nozzle Mix at the bottom of the tube. With the rocket nozzle mix cavity in place, the flame and hot gasses pass through the small vent hole in it, which they cannot burn through, so the hole stays at 1/8" all through the flight. See the illustrations below:





As you can see from the illustrations, the plug/cavity ramming tool is nothing more than a wooden or metal rod with the end ground down to a point, that slips easily into the cardboard tube. The best choice for making the tool is aluminum or steel. You're going to be pounding on this thing with a hammer, so one made of wood probably wouldn't last you all that long. You'll also need to make an identical ramming tool without a point on the end. This will be used for compacting the propellant into the tube. The step-by-step procedure follows.

PROCEDURE

Propellant: Most rocket propellants are suitable, particularly those that produce interesting sparks. The following composition works well, and several more may be found in the [Collection of Pyrotechnic Compositions]().

CHEMICAL	PERCENT/PARTS
Potassium nitrate	68
Charcoal	14
Sulfur	9
Aluminum	9

Clay: The nozzle and end plug are formed from clay, much like as is done in the construction of rockets. As will be described shortly, the nozzle shape is different though. Bentonite, kaolin and ground kitty litter all work well.

Tools: A sleeve and rammer, such as used in the construction of rockets, are used for this project as well. Besides a flat-ended rammer, an unconventional rammer will also be needed. With some patience, it can be made by evenly filing down one end of a straight rod. Alternatively, you could drill a lengthwise hole of 5 mm diameter in the center of a flat ended dowel and fix a short length of 5 mm rod in that (much like as is done in the construction of a spindle).

CONSTRUCTION

Nozzle End

Buzz bombs differ from rockets in that the exhaust from the nozzle is projected sideways, exerting a torque. Clay is used to provide a more or less erosion resistant exhaust hole.

Propellant, End Plug, & Exhaust

Ram or press the propellant in small increments, each no more than will give a layer as thick as half the casings inner diameter to prevent wrinkling. The other end of the casing is filled with clay to form the end plug.

The exhaust hole is drilled through the side of the casing. This is a somewhat dangerous operation since it causes quite a lot of friction but as we do not need to drill a great length through the propellant and the propellant is quite insensitive, the risk can be considered acceptable (of course, a blast screen and proper protective clothing should still be used). Carefully drill a 1/8" hole through the side of the casing about 5/8" from the end. Drill halfway through the casing; the hole should reach just into the (now propellant filled) cavity in the clay plug, as illustrated in the images above.

Wings

Wings can be purchased from many different pyro supply companies.

Assembly

Glue the wing to the casing with some **hot glue**. Take care to orientate the exhaust hole properly with respect to the wing. Insert a piece of fuse into the exhaust hole (2 1/2" of **visco** is adequate) and fix it in place with a drop of hot glue.

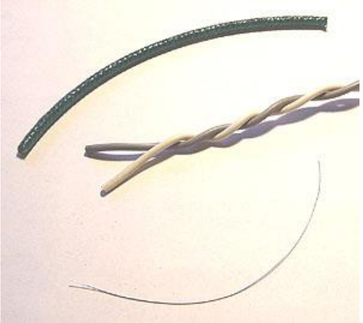
DANGERS

Place on the ground with the casing resting on the ground and the wing on top. Light fuse and get away. Keep well away from these items. They are somewhat unpredictable and may bounce around on the ground instead of climbing into the air. Like rockets, they may explode if the propellant is not compressed well. The end plug or nozzle may also be blown out which can be hazardous.

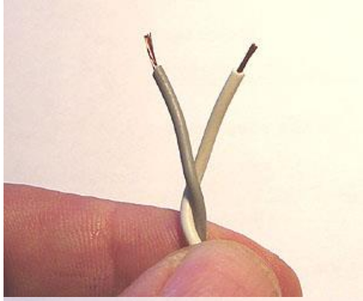
THE NICHROME/FUSE IGNITER

Nichrome (pronounced nye-chrome) wire is a blend of nickel and chromium metals. This metal has the unique property of increasing its electrical resistance when current flows through it, causing it to glow red hot. In short, a thin piece of nichrome wire will quickly heat up when even a small voltage is applied to it. This makes it perfect for igniting fireworks, miscellaneous pyrotechnic items, and rocket motors from a safe distance at the push of a button. There are several different variations of making electrical igniters, but they are all basically the same. Here are a couple:

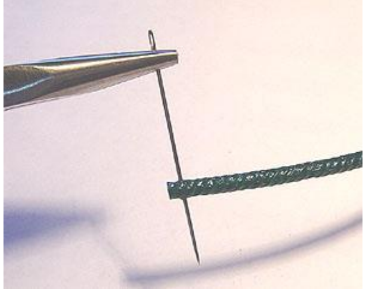
The nichrome/fuse igniter is easy to make from available materials, and has the extra safety advantage of a short delay produced by the fuse. This is the best igniter to use for smaller black powder type (Estes or homemade) rocket motors.



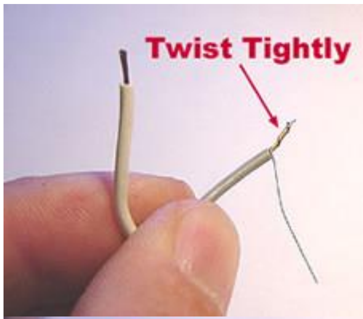
The materials needed for the nichrome wire/fuse igniter are: a short length of **Visco Safety Fuse**, about 1.5" of nichrome wire, and some insulated wire. You can use just about just about any type of insulated wire (speaker wire, alarm hook-up wire, etc.; all available at Radio Shack or your local hardware store). Stranded wire is generally easier to work with, and much more flexible than solid wire. It's best to use wire no thinner than 20 gauge. If you plan on running the wires a long distance like 20 or 50 feet for launching model rockets, etc., then 16 gauge or 14 gauge wire would be better. The lower the wire gauge number is, the thicker the wire, and the less power it will take to fire the igniter.

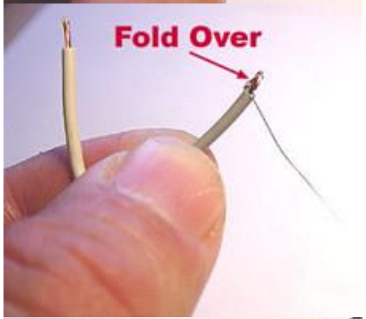


Strip about 1" of insulation off the end of each wire.

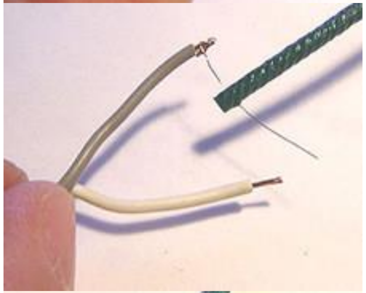


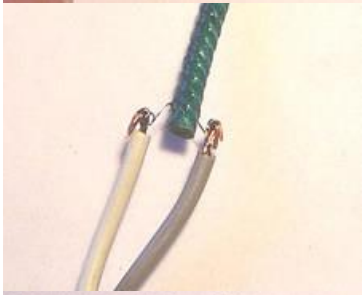
Using a sewing needle and pliers, push the needle through the end of the fuse to make a small hole.



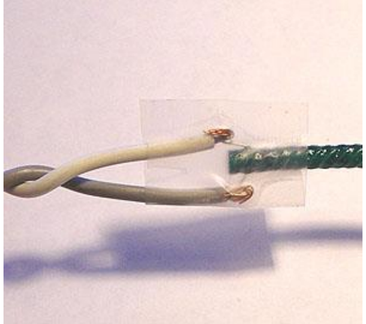


Twist the nichrome wire tightly around one of the wires and fold over so it is secure.





Insert the other end of the nichrome into the small hole in the fuse and connect to the remaining wire by twisting and bending over as you did before. Make sure the two ends of the wire are not touching each other, or the igniter will not work.



Finally, fold a piece of tape over the connections so it protects them and prevents them from touching each other. When power is applied to the opposite ends of the wire, the small piece of nichrome will heat up, glow red hot, and ignite the fuse. Depending on how long your wires are, and how thick the wire you used is, as little as 3 volts (2 flashlight batteries) will be sufficient to make the igniter work. Long lengths of wire may require as much as 12 volts, and very long runs may require even more.

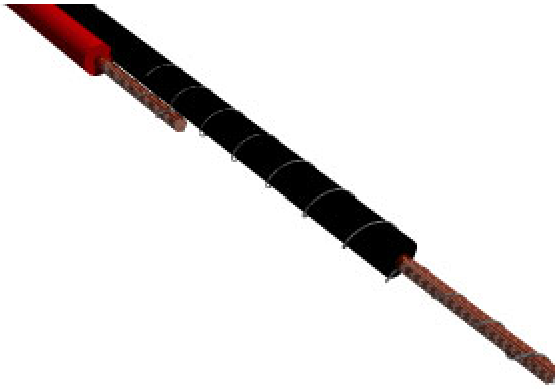
ANOTHER METHOD

This information will show you how to make a highly reliable, fast burning, and very high temperature rocket motor igniter. This thing burns hotter than 3500 (F) and will light reliably and quickly on a car or motorcycle battery. These igniters include Magnesium powder and potassium nitrate. These two ingredients should never be mixed dry as they become an explosion hazard.

What You'll Need:

1. 1.5" piece of soda straw
2. 6" piece of bi-pole insulated copper wire (22-24 awg)
3. 1.5" piece of 30 awg Nichrome wire
4. Wire cutter/strippers
5. Soldering iron
6. Solder
7. Soldering flux
8. 6 g KNO3 (Potassium Nitrate or Saltpeter)
9. Epoxy
10. Magnesium Powder (preferably > 300 mesh)
11. Mixing cup

Procedure:



[Fig.1. Detail of method for wrapping nichrome wire]

1. Strip both leads of one end of the bipole-insulated wire, making sure that one lead is approximately .7" shorter than the other (see Fig. 1).
2. Take the nichrome wire, wrap it first around the stripped copper of the longer lead, then wrap about 5-6 turns around the INSULATED part of the longer lead before wrapping also around the uninsulated part of the shorter lead (see Fig.1).
3. Take some soldering flux and put it on the uninsulated part of the wire where you wrapped the nichrome. Solder the nichrome wire wrappings to the uninsulated wire.
4. Mix together a pyrogen consisting of 6g KNO3, 2.5g epoxy resin and hardener, and 1.5g Mg powder. Make sure to mix the magnesium powder into the wet epoxy fully before adding the KNO3, as this will greatly reduce the risk of flash explosion with this mixture. Push this mixture into the 1.5" soda straw.
5. Push the nichrome-wired end of the bi-pole wire into the pyrogen in the soda straw. Allow to cure.
6. Cut a slit down the soda straw and peel it off of the hardened pyrogen.

Your igniter is finished!

FIRE BALLS

#1: NAPHTHALENE FIRE BALL

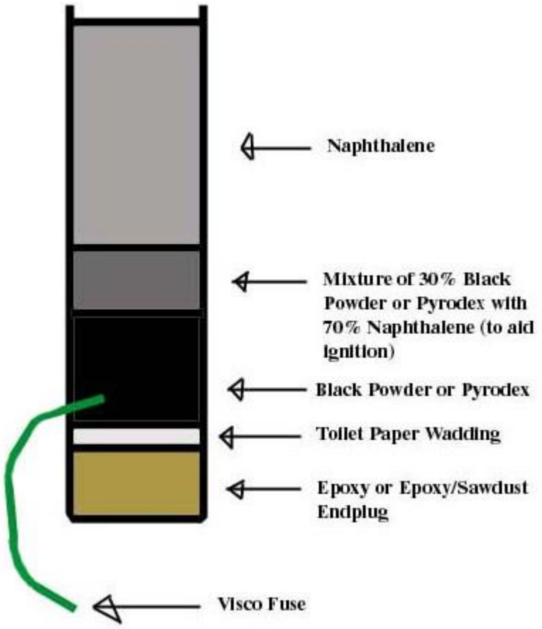
Naphthalene (formula C10H8) is a white volatile solid available in the form of mothballs. Be careful when purchasing the mothballs, as most mothballs nowadays are made of paradichlorobenzene, which will not work. Check the package; it will say either "Guarantee: 99% Paradichlorobenzene," or "Guarantee: 99% Naphthalene." Buy the "99% Naphthalene" type.

MATERIALS:

Large **Parallel-wound paper tube**
1/8" Visco Fuse
1/8" Drill or nail
Mortar & Pestle or coffee grinder
99% Naphtalene Moth Balls
Black Powder or Pyrodex (NOTE: Smokeless Powder will NOT work for this. Black Powder works a bit better than Pyrodex, but Pyrodex still produces satisfactory results)
End Plug Material (Epoxy, sawdust, clay, wood, **hot glue**, etc.)

PROCEDURE:

1. Take a large parallel-wound paper tube (the exact dimensions are not important. Big tube=big fireball, so experiment!) and plug one end with an epoxy/sawdust, clay, wood, hot glue etc. end plug and allow to cure completely.
2. Drill a 1/8" hole just above the end plug and insert a length of Visco Fuse; glue if necessary.
3. Fill 1/4th of the tube with black powder or pyrodex, making sure it does not get packed or tamped.
4. Pulverize the naphtalene with a mortar & pestle or coffee grinder until it is a powder. Mix 30% by weight of BP/Pyrodex with 70% by weight of powdered naphthalene and fill about 1/8th of the tube with this mixture.
5. Fill the remaining 5/8ths of the tube with powdered naphthalene.
6. Bury in the ground until only 1" of the tube is sticking out. You're done (if any of this has confused you, see the diagram below)! Light the fuse and RUN!!!!!


Naphthalene
Mixture of 30% Black Powder or Pyrodex with 70% Naphthalene (to aid ignition)
Black Powder or Pyrodex
Toilet Paper Wadding
Epoxy or Epoxy/Sawdust Endplug
Visco Fuse

#2: CREMORA FIRE BALL

MATERIALS:

Non-Dairy Creamer (powdered) - Cremora is a popular brand
Parallel-wound paper tube
1/8" Visco Fuse
1/8" Drill or nail
Black Powder or Pyrodex (NOTE: Smokeless Powder will NOT work for this. Black Powder works a bit better than Pyrodex, but Pyrodex still produces satisfactory results)
End Plug Material (Epoxy, sawdust, clay, wood, **hot glue**, etc.)

PROCEDURE:

1. Take a parallel-wound paper tube (the exact dimensions are not important. Big tube=big fireball, so experiment!) and plug one end with an epoxy/sawdust, clay, wood, hot glue etc. end plug and allow to cure completely.
2. Drill a 1/8" hole just above the end plug and insert a length of Visco Fuse; glue if necessary.
3. Pour in 10 grams of black powder or Pyrodex, making sure it does not get packed or tamped. Use more for larger tubes.
4. Fill the rest of the tube with non-dairy creamer.
5. You're done! Bury in the ground until only 1" of the tube is sticking out. Light the fuse and RUN!!!!!

NEGATIVE-X

COMMENTS: It's a good idea to mix this formula and conduct this experiment outside. Take about a teaspoon full of the mixture and make a small pile of it on the ground. Add a drop of water and quickly stand back. In a second it will bubble, hiss and smoke, and instantly burst into a blue-green flame. If you're really bored, you can make a few piles of Negative-X on the ground and try and hit them with a water pistol from a distance away.

WARNING: Don't store this stuff; use all that you make each time you make it. Eventually (depending on how humid it is where you are), it will absorb enough moisture from the air (or whatever else it is touching) and ignite itself without warning!

This is NOT something you want to mix on a rainy day.

PREPARATION (parts by weight)**:**

CHEMICAL	PERCENT/PARTS
Ammonium nitrate	28
Ammonium chloride	3
Zinc dust	69

Grind the ammonium nitrate and the ammonium chloride together with a mortar & pestle until they are a fine powder. Add the proper amount of zinc dust and mix well.

Note that as soon as this is mixed, it becomes very water sensitive! Even a tiny amount of water will ignite the mixture. You must use this composition immediately after it is made - DO NOT STORE IT for any length of time, and do not mix it with other chemicals.

Here's the chemical reaction that takes place:

1. Cl^- (from NH_4CL) acts as a catalyst on the decomposition of NH_4NO_3:
   $Cl - NH_4NO_3$-----------------> $N_2O(g) + 2\ (H_2O)(aq)$
2. Water in the reaction causes the decomposition of more NH_4NO_3, which is an autocatalytic effect.
3. The reaction melts the NH_4NO_3 and allows the oxidation of the zinc. The overall reaction is:
   $Zn\ (s) + NH_4NO_3\ (s)$------> $N_2\ (g) + ZnO\ (s) + 2\ (H_2O)\ (g)$

SMOKE BOMBS

By far, the most common smoke formula is the Potassium Nitrate/Sugar formula. It produces a white-gray smoke and is easy, inexpensive, and fun to make. The percentage of potassium nitrate and sugar in this composition vary somewhat depending on who you ask, but the 60/40 mix listed below is pretty common.

A lump of this stuff the size of your thumb produced the smoke cloud in the image below in under 2 seconds.

CHEMICAL	PERCENT/PARTS
Potassium nitrate	60
Sugar	40

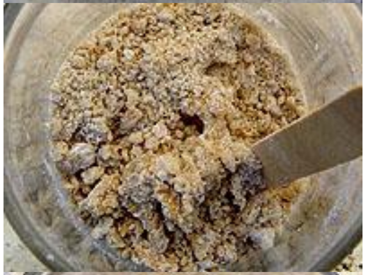
Although the two ingredients can just be finely powdered and mixed together, in recent side-by-side tests, we found that melting the two together does, in fact, make a superior Smoke Bomb. To melt the mixture together, you'll need small metal saucepan (or other heat resistant container) and an electric hot plate. An electric hot plate is preferred to an open flame heat source because it's a tad safer, and easier to prevent overheating of the mixture. The mixture must be heated SLOWLY, and over a LOW heat until it just starts to melt. Heating it too quickly, or at too high a temperature will cause it to turn black, burn and ignite, creating a giant mess AND a fire hazard. In any case, this should all be done outside, just in case you overheat it and it does happen to ignite. As the mixture begins to melt, it will turn brown and look very similar to caramel candy or peanut butter (see image above). After all, you are melting sugar (and no, you can't eat it).

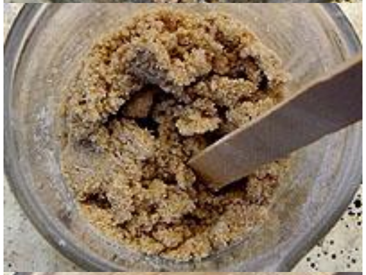
PROCEDURE:

Start by making a small batch (50 grams total). Measure out 30 grams of potassium nitrate and 20 grams of sugar into a small cup. For those of you who cut math class, 30 grams of potassium nitrate and 20 grams of sugar is still a 60/40 mixture. If you make a batch larger than 50 grams, it will be very difficult to mix and heat evenly. You can always make more, so don't mix up a giant batch.

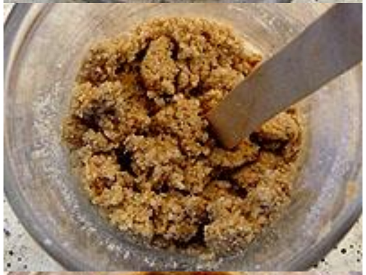
Snap a lid on the container and shake to mix the two chemicals together. Pour the mixture into a heat resistant container and set it on your hot plate.

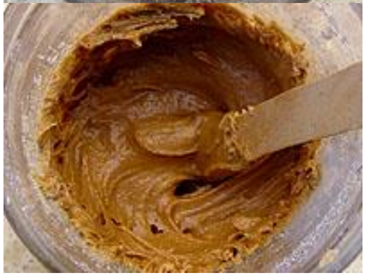
Set the hot plate temperature to medium-high, and about every 30 seconds or so, stir the mixture well, being sure to scrape the material that may start sticking to the bottom.





Over the next several minutes, the mixture will begin to darken and clump. It will soon begin to look like brown sugar, and when it finally mixes smoothly and looks like peanut butter, it is done. If your mixture is turning BLACK, you're heating it at too high of a temperature.





Remove the container from the heat and scoop out a lump of the sticky mass. You can either just plop some on the concrete, or if you're picky about the way your smoke bombs look, you can make small cardboard molds and press the gooey mass into them. Personally, we just lay it on the concrete.

Before the little blob cools, insert a small piece of Visco Safety Fuse.

Do this with the remainder of the material, and allow them to cool and harden.

In about 5 minutes, the material will be cool and become rock hard (beware that it will stick to the surface while cooling, but is easily removed with a little knock from a hammer). Set your Smoke Bomb away from any flammable materials, light the fuse, and stand back!

The smoke from this mixture is essentially non-toxic, but that doesn't mean you should stand in a cloud of it and breathe it all day long. Like any smoke from burning material, people may be allergic to it, or it may cause eye irritation in some more sensitive folks.

Colored Smoke

Unfortunately, colored smoke mixes are a totally different animal. The nitrate/sugar mix cannot be colored. Colored mixes use an entirely different cool-burning mixture and vaporize special low-temperature dyes to produce colored smoke.

STAR MINES

Star mines are devices that fire a cloud of stars up into the sky. The effect is short but spectacular; these are very commonly used in professional displays. In the mine, a lift charge and some stars are placed, and when fired, the stars are shot upwards and will reach 30-60 feet and rain down, burning out before they reach the ground. The effect is spectacular, especially with the somewhat larger ones. Smaller are much less spectacular, and larger is more dangerous. In general, it's better to start out small.

MATERIALS:

Casing: Heavy-walled paper tube.

End plugs: Toilet paper or tissue paper is used for one end plug. The other is either made from wood, clay, epoxy, hot glue, plaster etc.

Fuse: Visco Fuse.

Lift charge: Black powder works well.

Stars: Some stars are needed, of course. Use between 30 and 50 stars of 3/8" to 5/8" diameter. You want the star mine to withstand the pressure from the lift charge and build up sufficient pressure to fire the stars high up in the sky, therefore the 'open' end should not be actually open, but closed as to slightly resist the lift charge.

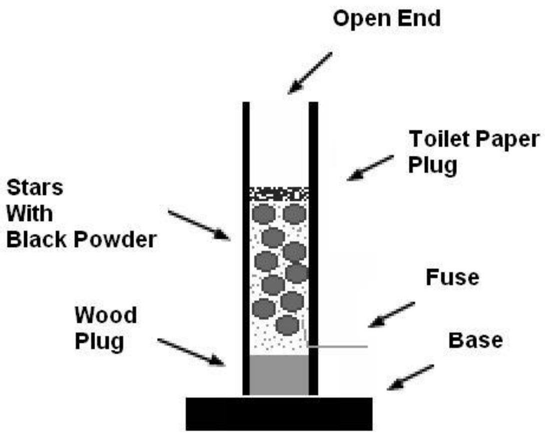
PROCEDURE:

Tube: Take a 2" length of dowel that is the same diameter as your tube and slide the tube over it, stuff several wads of toilet paper in the end of the tube and use a dowel and a hammer to compact the paper tightly in the tube. Continue until the paper plug is about 3/8" thick and then take the dowels out.

Fuse: It is better to add the fuse before the lift charge and stars. The fuse is inserted through a 1/8" hole in the side, about 7/8" from the bottom. Insert a long piece of Visco Fuse, twist it around the tube gently, and tape it lightly so that it won't be in your way.

Contents: The star mine contains some stars and a lifting charge. You can use just about any type of stars; fill about 3/4 of the star mine with them. Add the stars in small portions, taping the case after each addition to settle the stars. Black powder is used for the lift charge. If you use good quality black powder, a few grams (2 to 3 grams) will do. If you use inferior quality black powder (made without a ball mill), fill the star mine with black powder completely except for 7/8" of space for the end plug. Tap the case to settle the powder.

End Plug/Base: Finally, glue a wooden (or clay, epoxy, etc.) end plug in the tube with Elmer's or hot glue. Glue the entire star mine on a sturdy wooden base.



FIRING YOUR STAR MINE:

Pick an open area with no fire hazards. The main dangers of a star mine are fire, and the mine falling over or launching the stars horizontally instead of vertically. You should be far away from star mines, not just for safety but because they look better from a distance. It is also a good idea to partially bury the star mine.

WATERFALLS

The waterfall in the image at left is best made with a wire suspended between 2 poles approximately 20 feet high. Each thin paper tube, loaded with waterfall composition, is attached to the wire with its "starter end" pointing down. The tubes, separated by about 1 foot, are all ignited at once by a length of quickmatch. The bright white sparks float all the way to the ground; the traditional "waterfall" effect.
Attached to a stick, a single waterfall tube also makes an outrageous sparkler.

60-SECOND WATERFALL

PREPARATION (parts by weight)**:**

CHEMICAL	PERCENT/PARTS
Potassium perchlorate	46
Aluminum (bright)	23
Aluminum (flitters)	23
Dextrin	8

90-SECOND WATERFALL

PREPARATION (parts by weight)**:**

CHEMICAL	PERCENT/PARTS
Potassium perchlorate	46
Aluminum (bright)	14
Aluminum (granular, 50-150 mesh)	32
Dextrin	8

FOR EITHER (60- or 90-) COMPOSITION:
Roll ordinary 8.5" x 11" sheets of paper around a 5/8" diameter wooden dowel to form 8.5" long tubes (secure the end with tape). Moisten the composition until it just sticks together when squeezed. Using the dowel, press the composition, in small increments, into the tube. Leave a 1/2" space at the top for a starting mix. It is important that the tube burn away with the mixture, so don't pack the composition into thick cardboard tubes, just "roll your own" from sheets of paper as described. For a starting mixture, we use a blend of 75% waterfall mix and 25% black powder. Add just a little bit of water to it and press the mixture into the 1/2" space at the top of the waterfall tube. After these tubes dry (several days), hang them upside down from a long wire and light them all at once either electrically or with quickmatch. The bright white sparks will fall over 20 feet, producing a great waterfall effect.

WHISTLERS

COMMENTS: The reaction that causes the whistling effect is the layer-to-layer oscillating burn of the firmly compressed composition with the containment tube acting much like a resonator.

BE CAREFUL: This is a high energy mixture that can explode with friction/impact.

PREPARATION (parts by weight)**:**

CHEMICAL	PERCENT/PARTS
Potassium perchlorate	0.700
Potassium benzoate OR sodium benzoate	0.300

Grind the potassium perchlorate ALONE in a mortar & pestle until it is a very fine powder (unless it's that way already). Do the same to the sodium benzoate unless it is already as fine as Talcum powder. Note that the sodium benzoate must be VERY fine, and mixed VERY well with the potassium perchlorate for this mixture to work properly. Pass the mixture through a screen several times to mix the two together. It is important that this formula be mixed very well and be in a fine powered state. Pour the mixture into a Zip-loc plastic baggie, seal it, and shake it back and forth, just to make sure the composition is well mixed.

Don't ever grind the two ingredients together as the mixture may explode. Never grind, pound, or subject this mixture to friction as it may explode.

Seal off one end of a **heavy-walled cardboard tube** with Plaster of Paris, **hot glue**, or some rocket nozzle mix. The tube length should be 3 times the inside diameter. If the tube is too long, results will be poor. The larger the diameter of the tube, the louder and lower the pitch of the whistle. Experimenting with different tube diameters and lengths will reveal a variety of pitches and tones. Tubes with a 3/8” to 5/8” inside diameter work well.
Using a wooden dowel the same diameter as the inside of the tube, press small increments of whistle mix into the tube. Press hard to pack it in, but DO NOT bang on the dowel. Fill the tube only 1/2 full (whistles need a lot of empty space in the tube). Stick in a length of **Visco Safety Fuse** and make sure it touches the powder inside. Push the tube into the ground so it stays put, light the fuse, and get back!